Element-Specific Magnetization Dynamics in the GHz Range

Beamline: U4B and 4-IDC (APS, Argonne)

Technique: ultrafast time-resolved x-ray circular dichroism (XMCD)

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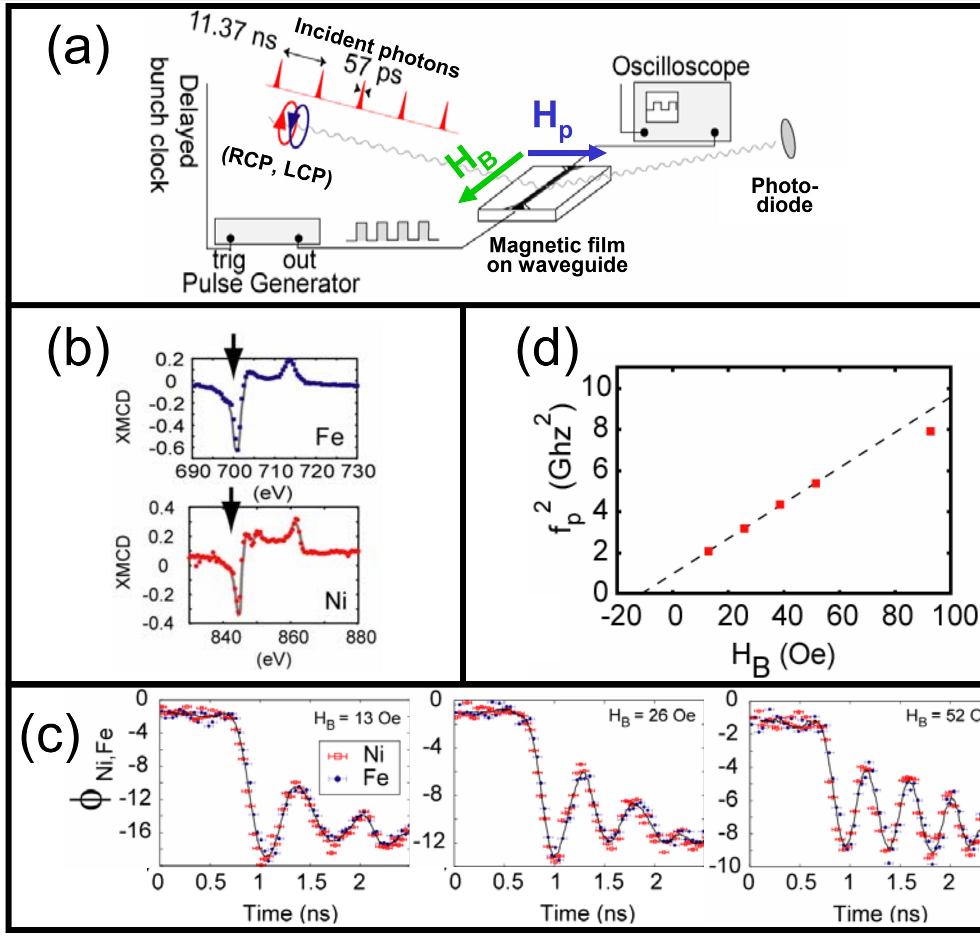
Publication:

W.E. Bailey *et al.*, “Precessional dynamics of elemental moments in a ferromagnetic alloy,” *Phys. Rev. B, accepted.*

Motivation: On ultrafast timescales, the change in direction of magnetization of a ferromagnetic domain occurs via precession. This oscillatory motion, with a characteristic frequency (f_p) of a few GHz, eventually damps out (Gilbert damping). In state-of-the-art magnetic recording devices, internal data rates already approach ~1 GHz. The precession frequencies and damping constants can be modified by alloying ferromagnetic materials with suitable dopants, but the connection between alloying and the modified dynamics is poorly understood. We developed the technique of ultrafast time-resolved X-ray magnetic circular dichroism (tr-XMCD) specifically to investigate the role of dopants in modifying Gilbert damping and to examine other aspects of magnetization dynamics on ultrafast timescales.



Results: (a) Schematic of pump-probe tr-XMCD experiment. A $Ni_{81}Fe_{19}$ ferromagnetic film is grown on top of a co-planar RF waveguide. Circularly polarized, ultrashort soft x-ray pulses (probe beam) are synchronized, with a variable delay, to an RF pulse generator. The RF pulses create a short magnetic field (pump field; H_P, blue) that initiates precessional motion. The reflected intensity of the soft x-rays is monitored by a photodiode. (b) XMCD spectra of the Fe & Ni edges. The arrows indicate the photon energies used to generate the tr-XMCD scans. (c) tr-XMCD scans at different bias fields (H_B, green) generated by external coils (not shown). Element-specific precession is clearly seen. (d) Kittel plot of f_p^2 vs. H_B. As expected, a linear relationship is evident.